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QUESTIONS

ON

LOCKYER'S ELEMENTARY LESSONS

IN

ASTRONOMY.

QUESTIONS

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LOCKYER'S ELEMENTARY LESSONS

IN

ASTRONOMY.

FOR THE USE OF SCHOOLS.

BY

JOHN FORBES-ROBERTSON.

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PREFACE.

THE following questions on Mr. Lockyer's "Lessons in Astronomy" have been framed with the object of bringing that work within the ready grasp both of teacher and pupil.

Seeing how eagerly this Manual has been welcomed by other nations, and fully satisfied myself of its value and completeness, I feel it would be matter worthy of public censure were not every facility afforded the English student for its intelligent and thorough comprehension.

The questions, in most instances, are intended to be direct and exhaustive; where they are not so, it is with the view of giving necessary latitude to the teacher.

To Mr. Lockyer, without whose encouragement I should scarcely have ventured upon these questions, I am indebted for several suggestions.

JOHN FORBES-ROBERTSON.

MOUNTFORT HOUSE, BARNSBURY,
Feb. 28*th*, 1870.

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QUESTIONS

ON

LOCKYER'S ELEMENTARY ASTRONOMY.

INTRODUCTION.

1. WHAT is the appearance of the sky on a cloudless night? How did the first astronomers picture the Earth in relation to the stars?

2. Why are not stars visible in the daytime? Give a familiar illustration.

3. Besides the Sun and stars, what other bodies are there in the heavens which attract our attention? How does the Moon differ from the Sun?

4. Give our name for what the ancients called "wandering stars."

5, 6, 7. What other phenomena are visible in the heavens?

8. What is implied by the word "universe"? Are all stars equally distant? Are they in motion, or stationary? Why do they appear to us to be at rest?

9. Why does the Sun appear so much bigger and brighter than the other stars? Illustrate this.

10. Why do the stars and the Sun shine? Whence is this heat derived?

11. What is a planet, and show how it differs from the Sun. Under what head would our Earth be classed? Is it likely that other stars have, like the Sun, planets revolving round them?

12. Does the Moon come under the same order as the Earth? Describe what you know of the Moon.

13. Describe the three principal classes of bodies already mentioned. What are *nebulæ* and *comets*, and how do they differ from the stars?

14. Give the relative sizes of the Sun, the Earth, and the Moon. How do the Earth and the Moon travel, and at what distance from each other and the Sun?

15, 16, 17. Illustrate the enormous distances in time and space dealt with in astronomy. Considering such immensity, are the methods of astronomers reliable and certain?

18. Wherein does physical differ from practical astronomy?

19, 20, 21. Enumerate a few of the advantages derived by mankind from the study of astronomy. From what is the word Astronomy derived?

CHAPTER I.

THE STARS AND NEBULÆ.

LESSON I.—*Magnitude and Distances of the Stars—Shape of our Universe.*

22. WHAT is the number of stars visible to the naked eye, and to what extent does a powerful telescope increase this number? How do astronomers express that variety in brightness noticeable in stars? To what extent is this classification carried in stars visible to the naked eye? How many magnitudes will a powerful telescope reveal?

23. Show the extent to which one star exceeds another in brightness, and what comparison the light of the Sun bears to that of the faintest star visible to the naked eye.

24. To what is the difference in the brilliancy of the stars probably owing?

25. What method do astronomers adopt to give an idea of distance?

26. How long does light require to travel from the nearest star (leaving out the Sun) before it reaches our Earth?

27. How long from a star of the first magnitude, of the second, and of the third? How long from a star of the twelfth magnitude?

28. What and where is the Milky Way, and of what is it composed?

29. What is the general arrangement of the stars with regard to the Milky Way?

30, 31, 32. Show how the *Milky Way* aids us in determining approximately the shape of our *Universe.* Describe, in reference to the Milky Way, the position of the Sun.

33. What are the *Magellanic Clouds*, and where are they situated?

LESSON II.—*The Constellations—Movements of the Stars—Movement of our Sun.*

34, 35, 36. How are the stars classified? To whom is the first classification due? Who was termed the Father of Astronomy, and how many stars had been observed by him? When did Ptolemy of Alexandria flourish, and when did Hipparchus? How many constellations did the catalogue of Ptolemy contain, and how many have been added since? Give the total number, ancient and modern?

37, 38, 39. What are the *zodiacal constellations?* How are they divided? Name them.

40. How are the stars in each constellation known and arranged?

41. Wherein do *star-maps* differ from celestial globes?

42. Name, in order of their brightness, the stars of the first magnitude.

43. Do the stars and various constellations move? and if so, has such motion in any instance been measured?

44. Describe and illustrate the Sun's motion.

45, 46. You have described these motions of the stars as their *proper motions.* Have they, then, other motions?

Lesson III.—*Double and Multiple Stars—Variable Stars.*

47. Describe and illustrate the appearance of stars when seen with a powerful telescope. Determine approximately the revolutions of (ε) *Lyræ.*

48. How many double stars are known? In how many of these has motion been detected? What is the relative brilliancy of such component stars? Give an example. Name some of the double stars, and the time in which a complete revolution is effected.

49. Give another name for such double stars. Give the astronomical reason for such name.

50. Are there any circumstances under which the dimensions of the orbit of one star round another can be determined, as we can determine the Earth's orbit round the Sun? Give an example.

51. Is the brilliancy of stars permanent? What do astronomers mean by *variable stars?* What are *new stars*, *lost stars*, and *temporary stars?*

52. How is this variation in the light determined and measured? What is the *period* of variability?

53. Name a few of the variable stars, and state the change of their magnitude and the period of their change.

54. Which are the most interesting among these variable stars, and why?

55. Among the new, or temporary stars, which are the most noticeable? Describe the appearances of the former, and say whether anything similar had been observed in the same region at any previous period. What is to be deduced from this?

56. Tell what you know of the *new star* which appeared in 1866. In what constellation was it seen? To what was its increased brilliancy in all probability owing? Is much importance to be attached to this fact?

57. What is Dr. Balfour Stewart's theory on the question of variable stars? What was the hypothesis formerly entertained?

58. Describe Dr. Balfour Stewart's theory a little more fully.

59. What would you infer from a planet's having a very elliptical orbit?

LESSON IV.—*Coloured Stars—Apparent Size—The Structure of the Stars—Clusters of Stars.*

60. Do stars vary in colour? Name a few large stars of different colours.

61. In what kinds of stars do we meet the most striking colours and contrasts? Give examples, and describe the effects of this wondrous colouring, especially as affecting the compound systems. What was the effect produced on Sir John Herschel by a group in the Southern Cross? Describe this group.

62, 63. Do the colours of stars change? Give an example. Are variable stars liable to such changes, and to what degree? Give an example.

64. Is the size or diameter of the stars ascertainable? When the Moon passes before such stars, what is the effect produced, and how long does it last?

65. Say what is known of the physical constitution of the stars. What is the photosphere of a star, and what the atmosphere? What are the materials of photospheres, and in what state do they exist?

66. Explain by familiar example the intensity of this heat.

67. Can the degree of heat in such photospheres be measured? Do we know anything of the substances which throw out this heat, and, therefore, light? Give examples.

68. Of what is the atmosphere of a star formed? How do such atmospheres affect the light given out by the photosphere? What is absorption? Give a familiar illustration. In what way is the occasional blood-red colour of the Sun at setting accounted for? Were such absorption in his own atmosphere, what would be the consequence? Do we know anything of the causes which produce changes in colours and brightness of stars?

69. What relation do the elements most widely diffused among the stars bear to those of our globe? Name a few such elements.

70, 71. What are the peculiarities of individual stars which have already been dealt with? Is there a tendency in stars to group themselves together? In what systems have we already seen the beginnings of such tendency? Give a few examples of this grouping or clustering of stars.

72. How are assemblages of stars divided by astronomers? Characterize these groups, and give their subdivisions.

73. In what manner are clusters and nebulæ designated by astronomers? Name a few of the authors of such catalogues.

74. Name such star-clusters as are best seen in moderate telescopes. Are all star-clusters fairly within the ken of our most powerful telescopes? Give the appearances of such immeasurably remote clusters, and name a few instances.

75. How is the brightness in such star-clusters distributed, and what is to be argued from such distribution?

LESSON V.—*Nebulæ—Classification and Description.*

76. What are *nebulæ?* Give its derivation, and exemplify the application of the word.

77. How has the telescope affected our knowledge of nebulæ?

78, 79. Are all so-called nebulæ, then, nothing but distant star-clusters? Is this an important discovery?

80, 81. Is this a very recent discovery? How are nebulæ divided? Name these classes.

82. Are any of the irregular nebulæ visible to the naked eye?

83. Where is the great nebulæ of Orion situated? Describe it, and tell what is known of it.

84. State what other irregular nebulæ are visible, and describe where. What apparent space do the nebulæ of Eta occupy?

85. Why are ring-nebulæ and elliptical nebulæ classed together? Give a striking example of each.

Is there anything remarkable about the nebulæ of Andromeda?

86. Give an example of the spiral or whirlpool nebulæ. Describe the appearance presented by an ordinary telescope. State the manner in which all this is changed by the use of a larger and more powerful instrument. Give examples of this strange phenomenon, and say what it indicates.

87. Who named the fourth class of planetary nebulæ? And why this name? Give illustrations of this class.

88. Describe the fifth class, or nebulous stars. Is the nebulosity of such stars resolvable with our present telescopes? Give examples coming under this class.

LESSON VI.—*Nebulæ (continued)—Their Faintness—Variable Nebulæ—Distribution in Space—Their Structure—Nebular Hypothesis.*

89. What are the next things to be considered in connection with nebulæ?

90. Have nebulæ, like stars, been divided into magnitudes? What equivalent have astronomers substituted? Describe the space-penetrating power of the telescope.

91. How remote must a star be before it can escape the scrutiny of such a telescope as Lord Rosse's? How long is light in reaching us from a star of the sixth magnitude? And how far off is such a star from one of the first magnitude?

92. Give an illustration of the extreme faintness of the more distant nebulæ.

93, 94. Have nebulæ any equivalent for the

phenomenon of variable, lost, new, and temporary stars? Give an illustration.

95. Compare the distribution of the nebulæ with those stars which form our Milky Way. In what parts of the heavens do nebulæ most abound?

96. What is a nebula? What question does this fact settle?

97. How are we to regard luminous and closely associated points of light in a true nebula? What suggestion has been offered in explanation of the apparent permanence of general forms in a nebula?

98. Does recent observation tend to confirm the nebular hypothesis given to the world before the existence of a nebulous fluid was proved?

CHAPTER II.

THE SUN.

LESSON VII.—*Its relative Brightness—Its Size, Distance, and Weight.*

99, 100. WHAT name do astronomers give to the star nearest to us? In what way does it affect the whole family of planets? Is there any reason to suppose that our Sun is a larger star compared with others? What proportion does the light of Alpha Lyra bear to that of the Sun? Compare Sirius with the Sun.

101. Is the distance of the Sun from the Earth now known? What is it? Does this knowledge enable us to determine its size? What is the *diameter* of the Sun? What do you mean by diameter? Do such figures convey any adequate idea to the mind? Assist the mind to form an idea of the relative sizes of the Sun and the Earth by showing how long a railway train, going at a certain rate, would require to accomplish the relative journeys round each. In a similar way, say how long a train would take to reach the Sun.

102. Give another familiar way of illustrating the distance and size of the centre of our system.

103. How many Earths would be required to make one Sun? How do astronomers express this? What is the weight of the Earth as compared with that of the Sun? How many Earths then would be required to balance the *mass*, or weight, of the Sun?

104. Has the Sun any motion similar to that of the Earth? How was this rotation discovered? Describe how these spots travel across the Sun, and their apparent paths at different times of the year.

105. Simplify and explain this still further, and, in doing so, describe what astronomers call *the plane of the ecliptic.* Is there anything in our globe which is put to an equivalent use?

106. Does the Sun float in an upright position through the plane of the ecliptic? What effect has the dipping down of the Sun's axis of rotation on his spots?

107. Have the sun-spots themselves any motion, and what is it called? Does the rapidity of movement of sun-spots vary? How is such variation regulated? How does this difference affect our notion of the Sun's rotation?

108. Do we know much of the physical constitution of the Sun? Why? What is the Sun's distance from our Earth? His diameter as compared with the Earth's? How large is the chasm called a sun-spot as compared with our planet? How near to the Sun does the most powerful telescope bring the naked eye? Is there any danger attending the use of the telescope?

LESSON VIII. — *Telescopic appearance of the Sun-spots — Penumbra — Umbra — Nucleus— Faculæ—Granules—Red Flames.*

109. To what parts of the Sun's surface are the spots limited?

110. In what do the spots float? What do astronomers call the half-shade shown in the spot? What the darker shade? And what the darkest?

111. What are sun-spots?

112. What does diligent observation of the umbra and penumbra with powerful instruments reveal? Describe these changes. To what extent did the great sun-spot of 1865 cover the surface of the Sun?

113. What have astronomers called those bright streaks of diversified form sometimes separate and sometimes uniting into ridges and network, which, even with a small telescope, we see near the edge of the solar disc? Of what magnitudes are these faculæ? What is the effect when they surround a sun-spot?

114. What great boon has the Sun himself bestowed in observational astronomy?

115. How, in a general way, would you describe the surface of the Sun? What has Sir William Herschel called the luminous masses of which the surface is principally made up, when seen through a large instrument?

116. What word describes and paints the appearance of the minute details *sometimes* observed in the penumbræ of spots? Describe further the occasional appearances of the penumbra.

117. What names have the Herschels given to the dark dots which often cover the shaded portions between the granules?

118. When the Sun is totally eclipsed, what other appearances unfold themselves which the brightness of the Sun prevents our observing under ordinary circumstances? What names have been given to these appearances? Who first discovered the means of beholding and examining them under ordinary circumstances?

LESSON IX.—*Explanation of the appearances on the Sun's Surface—The Sun's Light and Heat —Sun-force—The Past and Future of the Sun.*

119. How do we account for sun-spots? What is the probable nature of the photosphere of the Sun, and therefore of the stars? Wherein does the Sun's photosphere differ from the Earth's?

Of what is the atmosphere surrounding the photosphere composed? Is this atmosphere of an absorptive nature? What in all likelihood are the granules, and to what cause do you attribute their elongation in descending the slope of the penumbra?

120. What extent of surface do some spots cover, and what length of time do they continue? Are there periods during which more spots are seen than at others? What is the interval called?

121. Why may we regard the Sun as a *variable star;* and as such, what is his period? Is there any connection between this period and the action of the planets on the photosphere? Has the magnetic needle any relation with this period? What else are affected by a similar period?

122. What conclusion are we to draw from the various astronomical theories which attempt to account for sun-spots?

123. Give a list of the substances known to exist in the Sun. Of what does the atmosphere of the Sun consist? And to what height does that atmosphere extend?

124. What benefits do we derive from the Sun?

125. What is understood by the *relative* brightness of the Sun, and what by its *intrinsic* brightness? What is the lime-light? and compare it with the brightness of the Sun. Give Sir John Herschel's calculations on the subject.

126. What do we know of the Sun's *heat?* Give a rough approximation of the Sun's surface. How many tons of coal must be burned, therefore, in an hour, to represent the Sun's heat?

127. Does the sun send out, or radiate, its light and heat in all directions? What proportion of this light and heat does the Earth intercept?

128. Is there any other property in the Sun's rays besides light and heat? What is it called, and what are its effects?

129. What else does the Sun do besides building up the vegetable world? Illustrate this.

130. Illustrate further in what way the Sun benefits man. How would you describe man in his relation to the Sun?

131. Will the Sun, then, keep up for ever a supply of this force? Do philosophers know by what means the Sun's force is replenished? What was the probable past of the Sun, and what will be its probable future?

132. Wherein, on the whole, do the elements or stars differ from each other? What do you deduce from this? Is the probable past and future of the Sun the probable past and future of every other star?

CHAPTER III.

THE SOLAR SYSTEM.

LESSON X.—*General Description—Distances of the Planets from the Sun—Sizes of the Planets—The Satellites—Volume, Mass, and Density of the Planets.*

133. OF what bodies does the solar system consist? Describe these.

134. How many larger planets are there? Name these in the order of their distance from the Sun. How many small planets are there, and between what orbits round the Sun do they revolve? What is meant by the Zodiacal Light?

135. Do all the planets travel round the Sun in the same direction? What is that direction? What is the form of the path these planets travel?

136. Do you remember what was understood by the *Plane of the Ecliptic?* To what extent do the larger planets affect this level? Describe the relation of some of them to it.

137. Have planets any bodies travelling round them, as the Sun has? What are such bodies called? Name the planets which have satellites and apportion to each its ascertained number.

138. You have just said that the planets revolve round the Sun from west to east. Is the rotation of the planets round their own axes in a like direction? Is there any exception to this? Name it.

139. Name the distances of the planets from the Sun. Why are the planets necessarily nearer the Sun at one time than another? Do these miles measure the shorter or the longer distance? Name the periods of revolution round the Sun of these planets.

140. Give their diameters.

141. Give a familiar illustration of the comparative sizes of the Sun and the planets.

142. Do satellites vary in distances from the planets as the planets do from the Sun? What distance is the Moon's course from the Earth? and in what period of time is the journey performed? Does any satellite take a longer time to revolve round its primary than our Moon does to travel round the Earth? Which is it? Give the distances of other satellites from their primaries, and their periods of revolution. What is the diameter of the smallest planet, leaving the asteroids out of the question? Are there any satellites comparable to this in size?

143. What facilitated our knowledge of the *absolute* distances of the planets from the Sun? Knowing this, how would the sizes of the planets be determined?

144. Is it possible, under certain circumstances, to know the weight, or *mass*, of a planet? Or to compare the *density* of the materials of which it is composed with those we are familiar with here?

145. What do you understand by density? Bring out your meaning further by a comparison.

And if our system once existed as a great nebulous mass, how many times less dense must that mass have been than hydrogen?

146. What is the mean density of our Earth? Compare this with the density of the other planets. How does their relation to the Sun affect this density?

147, 148. Give the *volumes*, *masses*, and *densities* of the planets.

LESSON XI.—*The Earth: its Shape—Poles—Equator—Latitude and Longitude—Diameter.*

149, 150. Had men no proof of the Earth's being round, might we have guessed it? Why? But have we proof? What?

151. Give a further illustration of this.

152. What do you understand by the *sensible horizon?* Does this help you in any way to the conclusion that the Earth is spherical?

153. Give a familiar illustration of the motion of the Earth? What do you understand by the *North Pole* and the *South Pole*, the *polar diameter*, the *Equator*, and the *equatorial diameter?* Are these diameters of equal length?

154. To what did the ancients attribute the effects day and night? To whom are we indebted for having rendered the Earth's rotation visible to the eye? Describe his methods.

155. Describe his experiment in the Pantheon. What is the inevitable deduction?

156. Describe the action of such a pendulum swinging at either pole. How might it be made to serve the purpose of a clock? In what direction would the dial appear carried to a spectator

at the North Pole? And to one at the South Pole? Would this effect show itself at the Equator? Why not?

157. What was his second method? What is a *gyroscope?*

158. Show how the action of the gyroscope proves the rotatory motion of the Earth.

159. Describe the lines marked upon a terrestrial globe, and tell their object. How are all circles divided?

160. How many degrees, then, would the equator necessarily lie from either pole? What do you understand by the word *latitude?* How is this represented on the globe?

161. Is this sufficient to define the exact position of a place on the Earth's surface? How has the difficulty been got over? What name has been given to this mode of reckoning?

162. How frequently do *parallels* of latitude and *meridians* of longitude occur on the terrestrial globe? What other imaginary lines are there, and where? And what are the zones into which they divide the Earth's surface?

163. What is the polar diameter of the Earth? What the length of the equatorial diameter? Turn these feet into miles. What name, then, would you give to the shape of the Earth?

LESSON XII.—*The Earth's Movements—Rotation—Movement round the Sun—Succession of Day and Night.*

164. How long does the Earth take to turn on its axis, or polar diameter? What is the result to us of this movement? What other movement

has the Earth? What do we call the time in which that revolution is effected?

165. What do you understand by an ellipse?

166. Describe an easy method of making an ellipse upon paper. What are the foci of an ellipse?

167. Where is the Sun's position in the ellipse described by the Earth? What is the result of this? When is the Earth in *perihelion?* What is the derivation of the phrase? What expresses the opposite of this?

168. Do you remember what was said about the position of the Sun's axis in Art. 106? What is the position of the Earth's axis in relation to the plane of the ecliptic? Is this position always the same?

169. To what do we owe the succession of *day* and *night?* What, then, causes the *Seasons?*

170. Illustrate further the manner in which we get day and night.

171. How, then, is it that the days and nights are not always equal? When are the days and nights equal? What are these dates called? Give the derivation of Equinox. What is the *Summer Solstice?* Give the derivation. Where and when can the Sun be seen at midnight? In what direction is he? Where and when is he visible at noonday?

172. How would you divide the year at the poles? What is the length of the day and night at the equator?

173. Within what degrees of latitude are the days measured by hours, and in what by months?

174. In respect of day and night, and of the seasons, how does the southern hemisphere differ from the northern?

LESSON XIII.—*The Seasons.*

175. On what do the changes, to which the inhabitants of temperate zones are accustomed, depend? Prove this. How, then, are the changing seasons in the temperate zones caused?

176. Why do we see the Sun low down in winter and nearly overhead in summer? Illustrate this by a diagram.

177. Show how the Earth is presented to the Sun at the four seasons: that is, how the Earth would be seen by an observer situated in the Sun.

178. Is there any difference in temperature at the two equinoxes? Why?

179. Can we have the same time, as measured by the Sun, at all places alike? Explain this.

180. How many degrees does the Sun appear to travel in an hour? How much time would a degree of longitude thus represent?

LESSON XIV. — *Structure of the Earth — The Earth's Crust—Interior Heat of the Earth—Cause of its Polar Compression—The Earth once a Star.*

181. Describe the present appearance of the surface of our globe.

182. Was it always as it is at present? What do geology and physical geography say on the subject?

183. What do you understand by the Earth's crust? Classify these rocks.

184. Describe the order in which sedimentary rocks lie. Give a list of stratified rocks.

185. Give the reasons for supposing that such beds have been deposited by water, and mostly by the sea.

186. Are the stratified beds, of which you have just given a list, everywhere met with in the same succession? Explain this.

187. In what position do we often find sedimentary rocks?

188. Had such rocks retained their original horizontal position, what would have been the consequence? If found complete in any one locality, what is the estimated thickness of the series of sedimentary rocks?

189. Describe the nature of the disturbing force to which sedimentary rocks have been submitted. Give an example of an igneous rock. Wherein do such differ from stratified rocks?

190. Stripping the Earth, in imagination, of the sedimentary rocks, what have we reason to believe was the appearance of the surface of our Earth?

191. Illustrate this by a familiar example.

192. Have we any reason for supposing that the interior of the Earth is, at this moment, at a high temperature? What evidence have we of this?

193. At what rate does the temperature of the Earth increase as we descend? What would thus be the temperature of the Earth two miles down? Seven and a half miles? Eighteen miles? and twenty-eight miles?

194. What conclusion do you draw from this? To what might the Earth's crust be familiarly compared? Are philosophers agreed as to the

nature of the interior of the Earth? In what direction has the latest evidence pointed?

195. What is the density of the Earth's crust as compared with the Earth taken as a whole? How is this accounted for?

196. When is the Earth supposed to have assumed its present flattened shape? To what was this flattening due? Give an illustration.

197. Did the Earth conform to the law affecting fluid masses under similar circumstances? Who has proved this? Describe the nature of the experiments.

198. What grounds have we for believing that long ago the Earth was intensely heated, and fluid?

LESSON XV.—*The Earth* (*continued*). *The Atmosphere—Belts of Winds and Calms—The action of Solar and Terrestrial Radiation—Clouds—Chemistry of the Earth—The Earth's Past and Future.*

199. To what might the atmosphere of the Earth be likened? At what is the height of this atmosphere computed?

200. What are some of the phenomena of the atmosphere? On the Earth as a whole, do we find winds and clouds amenable to order? What are the main causes of all atmospheric disturbances?

201. Describe what we find on a map showing the principal movements and conditions of the atmosphere.

202. If the Earth did not rotate on its own axis, how would the trade-winds be affected? Describe the action of the winds towards the

equator, and how that action is modified. Describe also the laws under which the counter trades blowing towards the poles act.

203. How are these winds set in motion? What is the region of equatorial calms, and what the result? Whither do the upper currents found in the equatorial region go, and where do they descend?

204. What, then, is the cause of all this atmospheric change? Do the calm-belts and trade-winds remain stationary, or do they follow the changing position of the Sun with regard to the equator?

205. What proportion of the Sun's radiation into space sets in motion the prevailing wind-currents? What amount of heat does this represent?

206. To what do you ascribe the other phenomena of the atmosphere? What is the origin of clouds? What are the effects of heat and cold upon this aqueous vapour?

207. What are the chemical materials of which our planet, including its crust and atmosphere, is composed? Do all these elements enter equally largely into the constitution of the Earth's crust? Name the principal. To what extent is oxygen combined with the other elements forming the Earth's crust? Give examples.

208. What is the present chemical composition of the atmosphere? Besides the main constituents of nitrogen and oxygen, are there any others? Describe the atmosphere of the Earth when it was in a molten state, and the results of its cooling down.

209. What is it in the atmosphere which renders life possible? When will life in this planet become impossible? What, then, is the Earth's history, so far as we are acquainted with it?

210. Describe the nebular hypothesis. Why are stars self-luminous and planets not? Are we to suppose that it was always so? or that it will continue always so?

LESSON XVI.—*The Moon: its Size, Orbit, and Motions: its Physical Constitution.*

211. What is the size of the Moon? How many such would be required to make one Earth? How many Earths to make one Sun?

212. To what is the apparent size of the Moon attributable? What is the form of the Moon's orbit? What is the consequence of this? What is the Moon's average distance from the Earth? What her greatest, and what her least? What do you understand by the term perigee, and what by apogee?

213. How long does the Moon require to travel round the Earth? What is her revolution round the Sun called?

214. In respect of its motion, what has the Moon in common with the planets and the Sun? Is there anything peculiar in the case of the Moon's rotation? What results from this? Is there any inclination in the Moon's axis? What results from this? What term have astronomers given to this fact? Has the Moon other librations? Describe them, and how they affect the observer.

215. How is the plane in which the Moon performs her journey round the Earth related to the plane of the ecliptic? What is the plane of the ecliptic? What are the *nodes?* What do you

understand by the *line of nodes*, the *ascending node*, and the *descending node?*

216. Give a familiar illustration of the Moon's path round the Sun.

217. What do you understand by the "*Earth shine*"? Why does the portion of the Moon lit up by the Sun appear to belong to a larger Moon than the other? What is the effect called?

218. What is the average estimate of the Moon's light as compared with that of the Sun? Would the one-half of the sky visible to us have room enough for so many full moons? What conclusion do you draw from this? What proportion of the sky visible to us does the new Moon cover?

219. The Moon appears larger at rising and setting than when high up in the sky; is this really the case? Explain why the reverse is the fact.

220. How much will a powerful telescope magnify an object? How near, then, does such a telescope bring the Moon?

221. What were the dark patches in the Moon supposed to be before the use of large telescopes? What are they in reality? What are the bright markings on the Moon? Was ever the surface of the Moon similar to that of our own Earth? Compare the volcanoes of the Moon with those of our Earth.

222. What is the best way of seeing how the surface of our satellite is broken up? What do you understand by the *terminator?* How have astronomers managed to measure the heights of mountains and the depths of the craters in the Moon?

223. What are there observable on the surface

of the Moon besides *mountain ranges* and *crater mountains?* After whom have the principal of these been named?

224. Where is the walled plain Schickard? What is its diameter? What are the diameters of Clavius and Grimaldi? State the height of a few of the Moon's peaks as compared with that of some of our own mountains. How many mountains higher than Mont Blanc have Beer and Mädler measured? Is the proportion of the height of a mountain to the diameter greater in the Moon than in the Earth? Why?

225. What do we know of the present state of the Moon's surface? How is all this accounted for?

226. What are the *rilles?* How many are known? What are the bright *rays* seen at full moon? Explain them. Describe Mr. Nasmyth's experiment.

227. Why do we say that the Moon has no atmosphere?

228. What is the length of the Moon's day? Why is this? What results from the Moon's having no atmosphere? Tell what is known of the crater Copernicus.

LESSON XVII.—*Phases of the Moon—Eclipses: how caused—Eclipses of the Moon.*

229. What do you understand by the *phases* of the Moon? What is the position occupied by the *New Moon?* By the *Full Moon?*

230. What position does the Moon occupy at the *First Quarter* and *Last Quarter* respectively? When do we get the *crescent Moon* and when the *gibbous?*

231. Give, then, briefly the history of the phases of the Moon.

232. What is the separation of the illuminated from the dark portion of the Moon called?

233. Is the Moon's motion performed in the plane of the ecliptic? What would be the result were it so? What are such shadows called? Do ever such appearances occur? Under what circumstances?

234, 235. Give a demonstration of how an *eclipse of the Sun* occurs, also of the Moon.

236. Why is the shadow cast by the Moon in a solar eclipse more limited than the shadow of the Earth in an eclipse of the Moon?

237. Illustrate the meaning of *umbra* and *penumbra* by a familiar example.

238. Describe the appearance of the Moon during the progress of an eclipse. How long may a total eclipse of the Moon last?

239. What is the consequence if the Moon is not exactly at a node during an eclipse? Show this.

LESSON XVIII.—*Eclipses* (*continued*). *Eclipses of the Sun—Total Eclipses and their phenomena—Corona—Red Flames.*

240. In a total eclipse of the Sun, what is the average diameter of the shadow which falls on the Earth? Why does the shadow of the Moon travel more slowly than the surface of the Earth on which it falls? What is the longest time an eclipse of the Sun can be total? When was the last total eclipse of the Sun in London?

241. In eclipses of the Sun are there any visible

effects of umbra and penumbra? Describe the process of a solar eclipse.

242. Are there other eclipses besides total ones? Why is the Moon's shadow round and the Sun's pointed? What is the shape of the Sun's shadow? How does the length of this cone vary? State the length of the cone when the Moon and Sun are nearest and when furthest apart. But we saw in Art. 212 that the distances between the Earth and Moon varied: state this variation in miles. What is the result of this? When have we an *annular eclipse*, and what do you understand by the term?

243. Do ever *partial eclipses of the Sun* occur? Why, and how?

244. Are the nodes of the Moon stationary? What is their motion, and in what period of time does a complete revolution take place? What is the *nodical revolution of the Moon*, and its period? What do you understand by the *synodical revolution of the Moon*, and what is its period? When is the node in the same position with regard to the Sun? What is this called? After how many synodical revolutions of the node are the Sun and node alike situated? To how many synodical revolutions of the Moon are such nodic revolutions equal? and would the Sun and Moon be then alike situated? If, then, we have an eclipse at the beginning of the period, must we necessarily have one at the end? What is the length of a cycle of the Moon? What term have astronomers given to this period of 18 years and 219 days? Under what name was the period known to the Chaldeans and Greeks? What use did they make of their knowledge of this period?

245. Describe the appearance and effect of a total eclipse of the Sun.

246, 247. What is the appearance of the heavens a few seconds before the commencement of the totality of the eclipse? What the appearance of the Moon? What is the *corona?* Describe it. What is it supposed to be?

248. When the totality has commenced, what is seen within the corona of the Moon? Describe them. When were the more remarkable of these *red flames* or *red prominences* observed, and by whom? Can you give his description of what he saw?

249. What has been definitely established regarding these prominences? What is the height of some of them above the Sun's surface?

250. What are these red prominences supposed to be?

LESSON XIX.—*The other Planets compared with the Earth—Physical description of Mars.*

251. Can the facts which we have thus seen connected with our own planet guide and assist us in examining the others? What must we necessarily know, for instance, before we can calculate or make a diagram of a planet's path?

252. Is our knowledge of the rotations of the planets on their axes as satisfactory as our knowledge of their revolutions round the Sun? Give examples of the uncertainty of our knowledge in this respect.

253. With regard to those planets whose orbits are nearest to our own, is our information comparatively full? Which are these planets? Give

in a tabular form what we know of them. Can we therefore easily determine the number of days which go to make each planetary year?

254. Do you remember the inclination of the Earth's axis? How are Mars and Saturn in this respect? What is the inclination of Jupiter's axis? What is the consequence of this? What axis of rotation has Uranus?

255. Do the planets resemble the Earth in respect of the polar diameter being shorter than the equatorial? Give a table of the amount of *polar compression* in the various planets. What do we learn from this table?

256. What has the telescope enabled us to know of the physical structure of the planets—of Mars, for instance? Describe the sketch of it taken in 1862.

257. Describe the two drawings.

258. Explain how we are able to determine the length of the day and the inclination of the axis.

259. What has Mars in common with our Earth? What is the colour of the land, and why? What is the colour of the water?

260. If we are right in supposing that the bright portion surrounding the pole be ice and snow, what phenomenon ought to follow? Is this found to be the case? Is the thaw slow or rapid? When was this decrease very visible? To what is this rapid melting ascribed?

261. Explain what portions of Mars are visible to us, and under what conditions. Have maps been constructed showing all this?

262. What distinction is to be drawn between Mars and the Earth, which in other respects are so similar? What is the length of the seasons in Mars?

LESSON XX.—*The other Planets compared with the Earth (continued). Jupiter: his Belts and Moons—Saturn: general sketch of his system.*

263. Which is the largest planet in our system? Describe the appearance of Jupiter as seen through a powerful telescope. What are the *belts* of Jupiter?

264. Is the cloudy atmosphere of Jupiter stationary or variable? What results from these variations? What are seen besides the belts? What has the observation of such spots enabled us to determine? What is the rate of Jupiter's rotation? What effect would it have on the cloud-belts? Has Mars any cloud-belts? What is the probable reason?

265. What grounds have we for saying that the surface of Jupiter is never seen? Have all astronomers accepted these reasons?

266. Supposing the apparent volume of Jupiter and of Saturn is made up of a large shell of cloudy atmosphere and a kernel of planet, is there any reason why Jupiter's density should vary from that of the Earth or Mars? From what hypothesis would this save us? Has our own planet probably gone through a similar phase?

267. What besides belts and spots does the telescope reveal in connection with Jupiter? Describe these moons and their relations to their primary.

268. Wherein are Jupiter's moons similar to our Moon? What ground have we for thinking this?

269. What is a *transit?* Under what circumstance would a similar spot be seen sweeping over the Earth's surface?

270. What do we know of Saturn? Wherein does Saturn differ from Jupiter?

271. What is it about Saturn which interests us most? What were the conjectures of the earlier observers? Who discovered the true nature of the rings, and when? Do you remember the formula he used in announcing his discovery? Do you remember what sentence the letters make when properly transposed? Show, by enumerating the progressive discoveries connected with Saturn, how we are encouraged in the prosecution of the study of astronomy.

LESSON XXI.—*The other Planets compared with the Earth (continued). Dimensions of Saturn and his Rings—Probable nature of the Rings—Effects produced by the Rings on the Planet—Uranus—Neptune: its Discovery.*

272. Where is the ring-system of Saturn situated? What are its dimensions? What are the breadths of the three principal rings, and of the entire system? What is the distance between the two bright rings? What is the supposed thickness of the rings?

273. Of what, then, are these rings composed?

274. In what does Saturn resemble our Earth? How are these seasons indicated? Describe the appearance of the ring appendage as seen from the body of Saturn.

275. Describe the plane of the ring in its relation to the Sun. What follows from this? At night, therefore, what appearance will the lit-up surface of the rings have, and how will its position be indicated when not lit up?

276. If the rings eclipse the stars at night, do they affect the Sun by day? Show this. How long do these total eclipses of the Sun continue? What does all this help us to conceive? What is the length of Saturn's year? What follows from this fact?

277. Which are the remaining planets? When and by whom were they discovered?

278. Are Uranus and Neptune visible to the naked eye? Why not? Do we know anything of their physical peculiarities? What is there peculiar about the motion of the satellites of Uranus?

279. What led to the discovery of Neptune? Tell what you know about this grand discovery.

LESSON XXII.—*The Asteroids, or Minor Planets —Bode's Law—Size of the Minor Planets: their Orbits: how they are observed.*

280. What is Bode's law? Represent it in figures. The fifth term having apparently no representative, how did this affect Kepler and other astronomers? When was the blank filled up? What is the name of that planet? Up to 1870 how many asteroids have been detected?

281. Are any of them visible to the naked eye? What is the diameter of the largest minor planet, and what the diameter of the smaller ones?

282. Where do the orbits of such planets, for the most part, lie? What is their form? What width of zone do they occupy? What is the distance between Mars and Jupiter? Which is the planet nearest the Sun? What is its mean distance, and

how long does it take to journey round the Sun? Which is the most distant? What is the length of its year, and its mean distance from the Sun?

283. Wherein do the orbits of asteroids resemble those of comets? To what extent is the orbit of Pallas inclined to the plane of the ecliptic? To what extent Massilia?

284. As stars of what magnitude do the minor planets shine? What mode is adopted for their detection?

285. What theory is suggested to account for the existence of these little bodies? What fact helps this theory? Who observed this?

286. What has been concluded from the hazy appearance of Pallas? Is there any evidence for supposing that some among the smaller planets rotate upon their axes like the larger ones?

LESSON XXIII.—*Comets: their Orbits—Short-Period Comets—Head, Tail, Coma, Nucleus, Jets, Envelopes—Their probable Number and Physical Constitution.*

287. Besides planets, what other bodies revolve round the Sun? Show wherein comets differ from planets. Of what does a comet probably consist?

288. Give another name for the orbit of a comet. Describe a parabola. What do we know of comets with parabolic orbits? What of comets with elliptical orbits? Give the names of a few of these, and the facts regarding them as stated in the table.

289. What name have astronomers given to such comets? Give a few instances of the estimated

times of revolution of what astronomers call long-period comets.

290. Give instances showing how much the distance of these erratic bodies from the Sun varies in different points of the orbit. What was the result in the temperature of the comet of 1680 when it approached nearest the Sun?

291. Describe what a comet is like, and name its various parts. How many tails had the comet of 1744? How many that of 1823? Must a comet necessarily have a tail, or tails? What degree of transparency has a comet? Give a late example of this.

292. What number of comets has been recorded from the earliest times till our own? Why are we able to record more comets now than formerly? What do Norman chroniclers say of the comet which appeared in 1066?

293. What is the condition of a comet when distant from the Sun? What do we learn of them from the telescope? Does the motion of a comet increase as it nears the Sun? Describe what other consequences follow a comet's approach to the Sun. Of what is a comet's tail composed? What is the tail's invariable position in relation to the Sun? As the comet gets still nearer the Sun, what fresh fact forces itself on our observation? Illustrate all this by reference to the comets of 1858, 1861, and 1843. What was the length of the tail of the comets of 1861 and 1843? What was the diameter of the tail of the 1843 comet, and that of the nucleus? Are there any exceptions to the general law respecting comets? Name and describe them. Give an instance of the enormous effect of a near approach to the Sun.

294. What ideas were associated with comets in those times when less was known about them? On the contrary, what does modern science teach respecting them? Illustrate this by referring to what is known of the comets of 1861 and 1776.

295. Is there any instance on record of a comet's dividing itself? Say what is known of Biela's comet.

296. What may be the number of comets belonging to our system? Why do we see so few?

297. In the case of a comet without a nucleus, what is the probable composition of the coma? If the tail of a comet indicates the waste, what must necessarily follow from each return to the Sun? What would result from the reduction of a comet's speed? Has this effect been actually observed, and in what instance? To what has this effect been attributed? What is Sir Isaac Newton's calculation about a cubic inch of air at the Earth's surface? What consequently may be the weight of the tail of the largest comet?

LESSON XXIV.—*Luminous Meteors—Shooting Stars—November Showers—Radiant Points.*

298. Are falling or shooting stars of frequent occurrence in the heavens? What number of meteors may be often seen by the naked eye on a clear night? To what extent is this number increased when the telescope is used? In each volume as large as the Earth in the space included by its orbit round the Sun, how many of these small

bodies are there capable of furnishing a shooting star visible under favourable circumstances to the naked eye? Including telescopic meteors, to what extent would this number be increased?

299. How are these little bodies arranged in the space comprised by the solar system, and how do they travel? To what is the phenomenon which we call a shower of meteors due? Are there any of these groups well-defined? Has this explanation been in any way verified?

300. Illustrate the theory in reference to the November group, by showing how we would see it.

301. Why do we not have star-showers every November? What time does the mass of meteors require to perform its revolution? Where must the mass necessarily be before we can have another shower?

302, 303. In what way does the Earth, sailing along its path, reach the node, and encounter the mass of meteoric dust? What was the Sun's longitude at noon on the 14th November, 1866? To what point behind the Sun is the Earth's motion directed? Deducting, then, 90° from the Sun's longitude at the above date, what have we?

304. At what point consequently ought we to meet the meteoric shower?

305. Describe what was actually seen on the 14th November, 1866. Supposing the paths of the meteors had on this occasion been projected backwards, where would they have intersected? What have astronomers called this point, and where have you already shown its longitude to be?

306. How do you account for the apparent radiation from this point? What do we gather from this?

307. Is this conclusive proof that the meteoric hail was fairly directed against, and as fairly met by, the Earth? What fresh set of considerations arises, supposing one situated in the radiant point and able to see exactly the countries occupying the hemisphere of our planet facing the meteor at the moment it entered the shower, when it was in its midst, and when it emerged again? Had the actual number of meteors encountered by the Earth remained the same, would the apparent number have increased, and in what way?

308. What has been determined as to the shape of the orbit of the November star-shower? Where is its perihelion, and where its aphelion? What is its inclination to the plane of the ecliptic? What is the direction of the motion of the meteors?

309. Up to the present time, how many radiant points have been determined? In what respects do the meteors of particular showers vary from each other?

LESSON XXV.—*Luminous Meteors (continued). Cause of the Phenomena of Meteors—Orbits of Shooting Stars—Detonating Meteors—Meteorites: their Classification—Falls—Chemical and Physical Constitution.*

310. Take the case of a single meteor entering our atmosphere, and explain why it has such a brilliant appearance.

311. How small were some of the particles composing the November shower? At what height from our Earth did they begin to burn, and at what height did they disappear? Why

did they disappear? Of what kind of materials, as compared with those of aërolitic bodies, are the November-shower meteors composed?

312. Are there other star-showers visible besides those of November? Are they subject to similar laws? Are the cometary orbits of meteors apt to mislead one in supposing a body a comet when it is only a meteor? Give an example of this.

313. Is the mass of November and August meteors and shooting stars, generally, considerable? What is a *detonating mèteor?* Give an example. Do such meteors sometimes reach the Earth before complete vaporization takes place? What are such meteors called?

314. Give the various names applied to those bodies which, resisting the action of the atmosphere, reach the Earth.

315. What are included under the term *sporadic meteors?* What do we know about them?

316. Mention a few of the largest aërolitic falls known to modern times, and describe them.

317. Are these stones unlike any other natural product? Do we know their chemical elements? Name them, and state their proportions.

318. What compound unknown in terrestrial chemistry has been detected in these aërolites?

319. Can you enumerate the various elements found in meteorites up to the present time?

320. Who has studied these meteorites microscopically? What has he ascertained regarding them?

CHAPTER IV.

APPARENT MOVEMENTS OF THE HEAVENLY BODIES.

LESSON XXVI.—*The Earth a moving Observatory —The Celestial Sphere—Effects of the Earth's Rotation upon the apparent Movements of the Stars—Definitions.*

321. WHAT is the relative importance of the Earth's place in Nature? Give a familiar analogy.

322. What is its importance to us? Illustrate this.

323. Is it necessary that we take the motion of our observatory, the Earth, into account in describing the *apparent* motions of the heavenly bodies?

324. Were the Earth actually at rest, what would happen?

325. On the other hand, what would be the result were the Earth to go round the Sun as the Moon goes round the Earth, turning once on its axis each revolution? How would you divide or classify the apparent movements of the heavenly bodies, and by what are they regulated? Give a familiar illustration of this.

326, 327. Is the daily motion of the Earth different in different parts? Have we corresponding differences in the apparent motions of the heavens? Describe these differences. What is understood by the term *celestial sphere?*

328. Describe what may be called the *celestial poles;* the *celestial equator*, or *equinoctial;* the *zenith*, and the *nadir*. What divisions have astronomers given to the heavens which would be equivalent to our parallels of latitude and meridians of longitude? If we suppose the plane in which our equator lies extended to the stars, what points will it pass through? Above and below, then, what have we? What point in the heavens corresponds with the meridian of Greenwich in the measure of longitude?

329. Do we always define the position of a body in the heavens by saying that its declination and right ascension (in time reckoned from Aries) are so and so? What is this called? What do astronomers understand by the *sphere of observation?* What is the *visible horizon?* What the *rational* or *true horizon?* What a *vertical line?* How do we point out the position of a heavenly body in that portion of the celestial sphere visible in the horizon of a place at a given moment of time? What is understood by *altitude? Zenith-distance? Azimuth? Celestial meridian? Prime vertical?*

LESSON XXVII.—*Apparent Motions of the Heavens as seen from different parts of the Earth—Parallel, Right, and Oblique Spheres—Circumpolar Stars—Equatorial Stars, and Stars invisible in the Latitude of London—Use of the Globes.*

330. Explain why a star seems to rise; why it seems to culminate or pass the meridian, or transit; and when and why it is said to set.

331. Illustrate this by a diagram in which the observer is supposed to be at the north pole of the Earth.

332. Furnish a diagram in which the observer is supposed to be on the Earth's equator, and then describe the motion of the celestial bodies. Illustrate the same by a diagram in which the spectator is placed half-way between the equator and the north pole.

333. Suppose the spectator, instead of being at a point of the Earth's surface 45° north, were placed in lat. 45° south, what would be the apparent motion of the stars?

334. What evidently happens, then, so far as the spectator is concerned, if we divide the celestial sphere into two hemispheres, northern and southern?

335. How may those, then, in middle latitudes, and therefore we in England, advantageously divide the stars?

336. What was gathered from Figs. 22 and 24 as to the height of the celestial pole above the horizon of any place? Show this. In London, therefore, in lat. 51½°, what must necessarily be the altitude of the celestial pole? What class, then, will the stars within 51° of the north pole form? Into what class will those within 51° of the south pole fall? And in what latitude must the stars be which form Class III.?

337. What artificial aids have astronomers devised for the comprehension of these and similar inquiries?

338. How do we proceed to adjust the terrestrial and celestial globes? What is the present variation of the compass?

339. To what number of degrees must the north pole be elevated to correspond with the latitude of London?

340. How must the terrestrial globe be turned to represent exactly the lie and direction of the motion of the Earth? And in what direction must the celestial globe be turned to represent the apparent motions of the heavens to a spectator on the Earth's equator? What will the wooden horizon represent? Will the reason be then apparent why some stars never set and others never rise in these latitudes?

341. Where does the northern celestial pole lie at the present time? What is the star called which so nearly marks the position of the pole? Is the direction in which the Earth's axis points always the same? What follows from this? Name the most striking circumpolar constellation. What are the most noticeable stars in this constellation, and why? Mention a few other important circumpolar constellations. Name the principal southern circumpolar constellations. To which class do nearly all the other constellations belong?

342. What methods may one take to watch the apparent motions of the stars? What does one see from observing the Great Bear, for instance?

343. In what period is the Earth's rotation accomplished? What follows from this? What hinders us from beholding this grand procession of distant worlds in the daytime as well as at night?

LESSON XXVIII.—*Position of the Stars seen at Midnight—Depends upon the two motions of the Earth—How to tell the Stars—Celestial Globe—Star Maps—The Equatorial Constellations—Method of Alignments.*

344. What position do the stars we see at night occupy during the day?

345. What necessarily follows from the fact that we travel round the Sun? How do we show that the stars change?

346. Is every portion of the visible celestial sphere exposed to view during one complete revolution of the Earth round the Sun? At what rate does the portion of the heavens visible in the south advance from night to night? In what space of time is this degree passed over? And consequently, what period do the whole 360° require?

347. What is this advance a consequence of? What results from the solar day being longer than the sidereal one? Compare the apparent yearly, with the apparent daily, motion; and say in what ratio they affect the apparent motion of the whole celestial vault.

348. Illustrate this.

349. What is the best way to obtain a knowledge of the various constellations and stars? Show again, as in Arts. 337-9, how the celestial globe is adjusted for study.

350. Having thus rectified the globe, on what part of it do the constellations which are rising on the eastern horizon appear? On what part of the globe are those which are setting? Where on the

globe will the constellations in the zenith be, and where those on the meridian?

351. How, then, do you ascertain when a star will rise, culminate, or set?

352. In the absence of the celestial globe, what may the astronomical student have recourse to? How should such table and maps be used?

353. Which is the most marked constellation in the equatorial zone? How may the bright stars in this constellation be utilized with the view of finding surrounding stars? Give an example.

354. How does one recognize the constellation Hercules?

355. How Pegasus?

356. How should the student proceed in the acquisition of his knowledge?

LESSON XXIX.—*Apparent Motion of the Sun—Difference in length between the Sidereal and Solar Day—Celestial Latitude and Longitude—The Signs of the Zodiac—Sun's apparent Path—How the times of Sunrise and Sunset, and the Length of the Day and Night, may be determined by means of the Celestial Globe.*

357. Is the effect of the Earth's daily movement upon the Sun precisely similar to its effect upon the stars? To what do we owe the difference between star-time and sun-time; or, in other words, between the lengths of the sidereal and solar day?

358. Illustrate this by a diagram. Were the Earth at rest, could this difference have arisen? Of what, then, is the solar day a result?

359. Is the Earth's motion in its orbit uniform? What is the consequence of this?

360. In what way have astronomers shown the importance they attach to the apparent yearly motion of the Sun? Why was this necessary? How do they get over the difficulty of the Sun's distance from the celestial equator varying every minute? To what do astronomers apply the terms *celestial latitude* and *celestial longitude?* From what points may this latitude and longitude be reckoned? Explain the terms *heliocentric* and *geocentric.*

361. By what is the celestial equator in this second arrangement represented? How is the zodiac divided? Give the signs and symbols of the zodiac. When these signs were adopted, did the Sun enter the constellation Aries at the vernal equinox, and occupy in succession the constellations bearing the same names? Does he do so now? To what is this owing?

362. As these two methods are built, the one on the plane of the terrestrial equator, and the other on the plane of the ecliptic, what follows? If we further regard the centre of the celestial sphere as lying at the centre of the Earth, what must necessarily follow?

363. Why does the Sun necessarily cross and recross the celestial equator?

364. What must follow from this? At the vernal equinox, when does the Sun rise and set? To what kind of a star may it be then likened? As its daily path approaches the zenith, whither do its rising and setting points advance? When it occupies that part of the zodiac at which the planes of the ecliptic and equator are more widely separated, what have

we? To what kind of a star might the Sun be likened when in this position? As it descends through the autumnal equinox to the winter solstice, to what kind of a star is its apparent path similar? Where are the Sun's rising and setting points then? What is the derivation of *Solstice?*

365. Having rectified the celestial globe, as directed in Arts. 337-9 and 349, what should the top represent? What in this case is supposed to occupy the centre of the celestial globe? How is the varying meridian height of the Sun shown?

366. How would you represent the positions of the Sun and stars at noonday? How would you adjust the globe to represent sunset? And how sunrise?

367. In what manner is the *diurnal arc* described by the Sun at different times of the year shown?

368. Where is the Sun at noon and at midnight? What do you argue from this?

369. How is civil time divided? What convenience is there in this? Illustrate this.

LESSON XXX.—*Apparent Motions of the Moon and Planets—Extreme Meridian Heights of the Moon: Angle of her Path with the Horizon at different times — Harvest Moon — Varying Distances, and varying apparent Size of the Planets—Conjunction and Opposition.*

370. What is a lunar month? At what rate would she thus travel per diem, supposing her motion to be uniform? What would result were

the Moon's orbit exactly in the plane of the ecliptic? What then is the true position of the Moon's orbit? What follows from this? May the Moon herself be ever more than 5° from the Sun's path? Show this. What is the greatest difference between the meridian altitudes of the Moon?

371. Where is the Moon at midnight as regards the Sun? What follows from this?

372. Why does the time between two successive moonrises vary considerably? If the Moon's orbit were in the plane of the equator, would the intervals of her rising be always about the same? Why? Show, then, why the Moon approaches the horizon at vastly different angles at different times. When is the Moon's path parallel with the equator? How does this affect the intervals between two risings? What happens when she is near a node in Aries or Libra? Explain this by aid of the diagram.

373. Show under what circumstances the Moon will rise at nearly the same time on successive evenings. Describe what is meant by the *harvest moon.*

374. Why do the planets, when they are visible, appear to rise and set?

375. Do the distances of the planets from each other and from the Earth vary? Why? Do the distances of all from the Sun vary? To what is this variation limited?

376. Has the Earth, at some point of her path, each planet by turns on the same side of the Sun as herself? To what extent, consequently, must the extreme distances vary in each case? Describe what other variations there may be.

377. Can you name the average least and greatest distances of the planets from the Earth, not taking into consideration the variation due to the ellipticity of the orbits? To what do you ascribe the changing brilliancy of the various planets? Are the *phases* of the planets whose orbits lie between us and the Sun similar to those of the Moon? Why? Give a few examples of the difference of distance affecting the difference of size. Which of the superior planets exhibits a marked phase? What does that phase resemble?

378. How have astronomers distinguished between those planets which travel round the Sun within the Earth's orbit from those which lie beyond it? Name the *inferior planets.* Explain the phrases *inferior conjunction, superior conjunction, conjunction,* and *opposition.*

LESSON XXXI.—*Apparent Motions of the Planets (continued). Elongations and Stationary Points—Synodic Period and Periodic Time.*

379. If an observer could watch the motions of the planets from the Sun, what would he see? Show why the observer on the Earth does not enjoy like facilities. What are the only planets visible at midnight? Why are not the inferior planets visible at the same time?

380. What do you understand by the *eastern* and *western elongations?* What are these distances respectively? What is our only chance, then, of seeing the inferior planets? When

Venus is visible during a western elongation or an eastern elongation, what is she called?

381. Show, by means of Diagram 33, the meaning of *direct motion* and *retrograde motion.* What difference does the Earth's motion make to the times between two successive conjunctions or elongations?

382. As seen from the Earth, do the superior planets appear to reach *stationary points* in the same manner as the inferior planets? Is the reason for this the same? Explain the reason with the aid of the diagram.

383. As in the case of the inferior planets, will the only difference be, when we deal with the planet actually in motion, that the times in which these changes take place will vary with the actual motion of the planet? Give an instance.

384. Why is the period in which a planet regains the same position with regard to the Earth and Sun different from the actual period of the planet's revolution round the Sun? What do you understand by the term *synodic period?* Can you give the synodic periods of the different planets? Have these synodic periods been actually observed? Show how the periodic time of the planets have been actually found out, beginning with the Earth and Mercury.

385. Show how you know the periodic time of Mercury.

386. In what way are the periodic times of the Earth and Jupiter discovered? Which of the two in this case is the outside planet?

387. In what other instance may an equation be used? Illustrate this by the Earth and Mars.

LESSON XXXII.—*Apparent Movements of the Planets (continued). Inclinations and Nodes of the Orbits — Apparent Paths among the Stars — Effects on Physical Observations — Mars—Saturn's Rings.*

388. If the motions of the planets were confined to the plane of the ecliptic, what would these motions, as seen from the Earth, resemble? Do you remember the present inclinations and positions of the ascending nodes of the planets?

389. If a planet is nearer the Earth than the Sun at the time of observation, will its apparent distance from the plane of the ecliptic be greater, as seen from the Earth? Taking the distance of the planet from the Earth into account, will the distance above or below the plane of the ecliptic appear to vary as regularly when seen from the Earth as it would could we observe it from the Sun?

390. When a planet is at a node, where must it necessarily appear?

391. Show by Fig. 34, representing the path of Venus, as seen from the Earth from April to October 1868, that you understand clearly the apparent motions of the planets.

392. Show by reference to Fig. 35, representing the path of Saturn from 1862 to 1865, how the distance of a planet from the Earth influences the shape of its path. Show Saturn's relation during this time to the ecliptic and the equator, and state what is to be deduced therefrom.

393. By what, then, is the apparent path of a planet moulded? Illustrate this by reference to the position of the orbit of Mars.

394. Under what kind of conjunctions will two planets be brought nearest each other? On the other hand, what is the nature of the opposition most favourable for observation—say, in the case of the planet Mars? Upon what is the variation in the Earth's orbit really dependent? When do we see the southern hemisphere of Mars better than the northern one, and when is the northern hemisphere most visible? Why is the northern hemisphere better seen than the southern one?

395. Refer to Fig. 37, and show the effect of inclination in the case of the rings of Saturn. Under what circumstances is the ring of Saturn invisible? How often do such changes occur? and what is the condition in the mid-interval?

CHAPTER V.

THE MEASUREMENT OF TIME.

LESSON XXXIII.—*Ancient method of Measurement — Clepsydræ — Sun-dials — Clocks and Watches—Mean Sun—Equation of Time.*

396. FOR ordinary purposes, how is time measured? Have astronomers recourse to anything besides the Sun, and why?

397. Is this correct measurement of time an important part of practical astronomy? Why?

398. What contrivances had the ancients for the measurement of time? Describe the clepsydræ, and name the people using them. Show wherein they failed, and why.

399. What is the first mention we have of the sun-dial? Compare it with the clepsydræ. How did the ancients tell the time during the night? Exemplify this by reference to a classic author. Give an illustration of the method in mediæval times.

400. Give some idea of the construction of a sun-dial, and explain the principle on which it acts.

401. Does the distance of the Sun above the equator make any difference in the lateral direction of the shadow?

402. Practically, can we do without the cylinder? What are the simple requisites for a sun-dial? Explain how the style and dial may be placed.

403. What is the principle of clocks and watches?

404. To what period is the invention of clocks and watches ascribed? When, and where, was the first clock in England erected? Explain the principle of Tycho Brahe's clock. From what date does the clock, as an ancient measurer of time, commence? Under whose inspiration were they constructed?

405. Is the astronomer satisfied with such a measurement of time? What does the term *day* mean, astronomically? In common use, what is understood by it?

406, 407. Was it ever attempted to make clocks and watches keep time with the sun-dial? With what results?

408. State why the Sun's ecliptic motion is variable.

409. Explain the inequality of the real Sun's motion. Show by what simple rule you get the Sun's mean daily motion.

410. If the true Sun moved in the equator instead of in the ecliptic, how would mean time be determined?

411. Why must we suppose the mean Sun to move along the equator? In what way does this bring out the inequality of the solar days? Explain this further by reference to a celestial globe.

412. What is the uniform rate, then, at which we suppose the Sun to move along the equator? And whence do we suppose the mean Sun to have started? At what rate must the Sun proceed?

413. If the motion of the Sun were uniform,

at what period would a correct clock correspond with a correct sun-dial?

414. As, however, we know that the motion of the true Sun is not uniform, when does it move fastest, and when slowest? Taking this irregular motion into account, what correspondence do we find between the motion of the real Sun in the ecliptic and the motion of the mean Sun in the equator? When, and how often, do we find this agreement?

415. Mention the dates at which we shall find differences in time between the true and mean Sun, and state what these differences are. Explain the phrase *equation of time*, and its application.

416. What is the difference between the Earth being in perihelion and the Sun in perigee? When so, will the real Sun gain on the mean Sun, or otherwise? What consequently must be the relation of the movement of the dial to the clock? On the other hand, when the Sun is in apogee, what will be the consequence in respect of the mean Sun, and how will the clock then stand in relation to the dial? What will the equation of time therefore be?

417. Illustrate this by reference to Art. 415, and show what must be added or subtracted in November and February in order to get clock time. In November, then, when does the true Sun set in comparison with the mean Sun? And when in February? Does this explain the rapid lengthening of the evenings after Christmas?

418. In what manner do we really obtain mean time? Suppose the true Sun to be observed on the meridian of Greenwich, Jan. 1, 1868, what would be the apparent time at that meridian? What is the equation of time as given by the almanac at this

instant? How is this equation to be treated? What is therefore the corresponding mean time? Explain this formula further, by showing the mean Sun's relation to the meridian as compared to the true Sun.

LESSON XXXIV.—*Difference of Time—How determined on the Terrestrial Globe—Greenwich Mean Time—Length of the various Days—Sidereal Time—Conversion of Time.*

419. Enumerate the start-points for the reckoning of solar days, apparent and mean. What is the difference between the civil reckoning of the day and the astronomical? By what well-known rule is the latter determined from the former? Give an example.

420. How is the Sun, in reference to the centre of the Earth, affected by meridians? Is it different at other meridians—Greenwich, for instance? In a mean solar day how has the Earth, in its rotation from west to east, affected all other meridians? In what period do meridians distant from each other 15° pass the mean Sun? When, therefore, it is six hours after mean noon at a place 15° west of Greenwich, how many hours is it after mean noon *at* Greenwich? When it is noon at Greenwich, why is it past noon at Paris? Would Bristol in a similar way be behind Greenwich, as Greenwich was behind Paris?

421. What is the time used in all civilized countries? Is one meridian chosen in each country? What is it in France? What in Switzerland? Give

another name for Greenwich mean time. Before local time was quite given up, what was there peculiar about the church clocks in the West of England?

422. Explain how railway-stations on the frontier of two States have their time regulated.

423. Express in mean time the length of the apparent solar day, the mean solar day, the sidereal day, and the mean lunar day.

424. From what point is sidereal time reckoned? When the mean Sun occupies this point, what is the result? As this happens but at one time, how much does the sidereal clock necessarily lose as compared with the mean time one? When is the coincidence re-established?

425. Explain what a sidereal clock represents, and how it acts.

426. What, then, is sidereal time at mean noon? Explain this in other words.

427. Where do you find the sidereal time at mean noon for each day stated? Give the rule for converting mean solar into sidereal time; also the rules for converting sidereal into mean solar time.

428. Where are the tables of intervals given?

429. Illustrate, under Rule I., how you would convert $2h.\ 22m.\ 25{\cdot}62s.$ mean time at Greenwich, Jan. 7, 1868, into sidereal time.

430. Referring to Rule II., how would you convert $21h.\ 28m.\ 11{\cdot}36s.$ sidereal time at Greenwich, Jan. 7, 1868, into mean time?

431. If the place of observation be not on the meridian of Greenwich, how would you proceed? Illustrate this.

LESSON XXXV.—*The Week—The Month—The Year—The Calendar—Old Style—New Style.*

432. In what is the week unlike the day, month, and year? From whom do we get the names of the seven days of the week? Whence did they derive them? Name them.

433. We see at once the origin of our English names for the first three days; whence do we get the names of the remaining four? Name them, and give their Roman equivalents.

434. How is the month regulated? Explain what is understood by the *lunar month*, the *tropical month*, the *sidereal month*, the *anomalistic month*, the *nodical month*, the *calendar month*.

435. Give the lengths of these various months.

436. Define what you understand by the *year*. What is the *sidereal year*?

437. What is understood by a *solar*, or *tropical year*? Is it longer, or shorter, than the sidereal one? Why?

438. What is the *anomalistic year*? Compare it, as to length, with the sidereal one, and explain the difference.

439. Give the exact length of the mean sidereal year, the mean solar or tropical year, and the mean anomalistic year.

440. Who first discovered that the solar year does not contain an exact number of solar days? Who first reformed the calendar? Whose aid did he obtain? What course did he recommend? To what term has this alteration given rise?

441. Did this correction serve the purpose?

Why not? Who next undertook the correction of the calendar? What rule did he establish for the future?

442. By how much does this addition exceed the proper correction? What proportion of intercalations is there by this new arrangement? How many years must elapse before this amounts to one day?

443. When was the *Julian calendar* introduced, and when the *Gregorian?* When did we introduce the Gregorian calendar? Why was its introduction deferred so long? In what way did we make the correction? When made, what name did we give it? Is the old style retained in any country of Europe yet?

444. What would have been the consequences had this reform of the calendar never taken place?

445. Is the tropical year at present diminishing or increasing? At what rate is it diminishing? How much shorter is it now than in the days of Hipparchus?

446. If the tropical and the anomalistic year were of equal length, what would follow? What do you understand by the *line of apsides?* In what period does this line make a complete revolution? When is it calculated that the perihelion point will correspond to the vernal equinox?

447. Upon what does the length of the seasons, compared with each other, depend? What follows?

CHAPTER VI.

LIGHT.—THE TELESCOPE AND SPECTROSCOPE.

LESSON XXXVI.—*What Light is; its velocity; how determined—Aberration of Light—Reflection and Refraction—Index of Refraction—Dispersion—Lenses.*

448. WHAT does modern science teach concerning light? Do all wave-motions travel alike?

449. Is light the instantaneous thing it appears to the eye? Who first determined its velocity? Describe Roemer's method of ascertaining this. What was his conclusion? Has this fact been abundantly proved since his time? Mention one of the proofs.

450. Give a familiar illustration of what you understand by the *aberration of light*. We have seen that light travels 186,000 miles in a second, or about 10,000 times faster than the Earth does; has this velocity been experimentally proved? By whom, and by what means?

451. When is a ray of light *reflected*, and when *refracted*?

452. Why do stars appear to be higher above the horizon than they really are? Give an illustration.

453. How can the refraction of light best be studied? Illustrate this. Is there any law relating to the difference between the angles at which a ray of light enters and leaves the prism? State this law, and say what name has been given to this ratio. Does it vary in different substances? What is it for chromate of lead, for flint glass, for crown glass, for water?

454. After a beam has passed through the prism, and is received on a piece of smooth white paper, is refraction all we see? What is this lengthened figure of various colours called?

455. What is the breadth of the spectrum? What does the lengthened figure of the spectrum prove? What are the colours exhibited? What is this called?

456. What results if we pass the light through prisms of different material? What would result, for instance, if we filled a hollow prism with oil of cassia? How has this fact been formulated?

457. Does every species of light preserve its own relative place in the general scale of the spectrum, whatever be the medium between which the light passes? Does this hold good in degree as well as in order? Give an instance. What term have opticians given to this?

458. Show how what has been stated will enable us to understand the action of a common magnifying glass, or lens. What do you understand by the *focus* of a lens? What by the *focal distance*? Show how the action of a convex lens inverts the image. What is the *axis* of a lens?

459. Give an illustration of the lens in nature, and show by what action of the eye we see.

LESSON XXXVII.—*Achromatic Lenses—The Telescope — Illuminating Power — Magnifying Power.*

460. In what manner must the rays of light enter the eye before we can see? Why, consequently, are we not able to see when anything is placed quite close to the eye? In what way does the common magnifying-glass prove of service at this juncture?

461. Show the action of a convex lens when the object looked at is at a distance of some feet.

462. Explain what is understood by a *concave* lens.

463. Name and describe the different kinds of lenses.

464. What means have been adopted to prevent the image thrown by a lens from being coloured? What is such a lens called?

465. How has this been rendered possible? If we take two exactly similar prisms made of the same material, and place one on its side and the other behind it on one of its angles, what will result to the beam of light? What will result if we replace the second prism by one made of a substance having a higher dispersive power? Does this smaller thickness undo all the refractive work of the first prism? Is this exactly what is wanted?

466. How is an *achromatic* lens made?

467. Describe wherein a telescope resembles the eye, and wherein it differs from the eye. What may a telescope be called then?

468. Refer to Fig. 48, and describe the construction and action of the telescope.

469. What, then, has the telescope done? What is its power? Describe first its illuminating power.

470. Upon what does the magnifying power of the telescope depend?

471. Show the relation the eye-piece bears to the focus.

472. Describe the telescope made by Galileo. What is the action of the eye-piece? Do such eye-pieces affect the light in any way?

473. Who obviated this defect? What plan did he adopt? Is this construction invariably adopted? What is a *micrometer?*

474. What is the object of the telescope-tube? And of the draw-tube?

LESSON XXXVIII.—*The Telescope* (*continued*). *Powers of Telescopes of different apertures—Large Telescopes—Methods of mounting the Equatorial Telescope.*

475. What size of object-glass ought a telescope to have for ordinary uses? Will amateurs find a less size serviceable? What double stars will a telescope with a two-inch aperture reveal? A four-inch aperture, and a six-inch?

476. How should observations always be commenced and conducted? If a $3\frac{3}{4}$-inch object-glass is good, what power ought it to bear on double stars?

477. Why is the magnifying power of a good telescope always much higher for stars than for planets? Why does no increase in the size of stars follow the application of higher magnifiers?

478. Why is it always dangerous to look at the Sun directly with a telescope of any aperture above two inches? What obviates this danger? How is the object-glass to be properly adjusted?

479. What two qualities should a good glass possess?

480. Give an example of the accuracy with which a fine object-glass ought to refract the light transmitted.

481. What, then, can the largest refracting telescope really do? Who has constructed the largest refractor in the world? What is the diameter of its object-glass? How near does this instrument bring the Moon? Who made the largest reflector in the world? What is the diameter of its speculum, or mirror? What is its illuminating power?

482. To what uses does the astronomer put his telescope?

483. What is an *equatorial?*

484. Describe its arrangement.

485. Is it convenient to attach the telescope directly to the polar axis? To what, then, is it fixed?

486. How are telescopes mounted for other kinds of work?

LESSON XXXIX.—*The Solar Spectrum — The Spectroscope—Kirchhoff's Discovery—Physical Constitution of the Sun.*

487. What has a careful examination of the *solar spectrum* revealed to us? What do you understand by spectrum?

488. What are these colours, and what are their properties? What, then, is the threefold action of the sunbeam?

489. Illustrate familiarly the appearance and action of the Sun's rays.

490. To whom do we owe the discovery of the *prismatic* spectrum? Who discovered the dark lines crossing the spectrum? Why are they called *Fraunhofer's lines?* To whom do we owe the explanation of these dark lines? Who first proved the law which explains them?

491. How shall we observe the lines best? Describe the appearance of the spectrum. In observing the spectrum of a lighted match, what do we find? Give another experiment. Illustrate again by an experiment.

492. Do we find here, then, the germ of Kirchhoff's discovery? What rays are absorbed by the vapours of metals and gases?

493. What facts have been established by experimenting in this manner? Which of these three laws is the one established by Kirchhoff?

494. What, then, has become of those rays which the dark lines in the solar spectrum tell us are wanting? What theory is based upon the non-arrival of those rays represented by the dark lines in the solar spectrum? What are the chances against this hypothesis being right?

495. Who was the first to apply this method to the stars? Is the plan of structure similar in them to that found in the Sun?

LESSON XL.—*Importance of this method of research — Physical Constitution of the Stars, Nebulæ, Moon, and Planets—Construction of the Spectroscope—Celestial Photography.*

496. Show the importance of the facts contained in the last lesson from an astronomical point of view.

497. Are these experiments equally applicable to the stars, and do they produce like results?

498. Do the spectra of the nebulæ resemble those of the Sun and stars? Of what do they consist?

499. Describe Mr. Huggins's experiment and its results.

500. With what does the strongest line coincide, and to what is it due? With what does the faintest of the lines of the Nebula coincide?

501. What inevitable conclusion do we draw from this fact of the light of nebulæ consisting merely of a few bright lines?

502. How do we prove by the spectroscope that the Moon has no sensible atmosphere? How, on the other hand, does the spectroscope prove that the planets have atmospheres?

503. Describe the maps of spectra in the frontispiece, and show wherein they illustrate what has already been said.

504. What cases of coincidence have been observed and measured by Dr. Miller and Mr. Huggins in the spectrum of *α Orionis*?

505. Describe the spectroscope in Fig. 49, devised by Mr. Huggins.

506. Describe the Kew spectroscope in Plate XIII. made by Mr. Browning for Mr. Gassiot. What do you understand by a *direct-vision spectroscope?* How is this managed in the Herschel-Browning spectroscope?

507. What rays are used in telescopic and spectroscopic observations? What is it which enables photographers to take celestial objects? Who are the distinguished operators in celestial photography? What is the method which they adopt? Is it possible to take the Sun as Mr. De la Rue has taken the Moon?

CHAPTER VII.

DETERMINATION OF THE APPARENT PLACES OF THE HEAVENLY BODIES.

LESSON XLI.—*Geometrical principles—Circle—Angles—Plane and Spherical Trigonometry—Sextant — Micrometer — The Altazimuth and its adjustment.*

508. UPON what principles are the apparent positions of the heavenly bodies based?

509. What is a *circle?*

510. How is the *circumference* of a circle divided?

511. Describe an *arc* and an *angle.*

512. Wherein do the arc and angle of a large circle differ from those of a small one?

513. What is a *right angle?* And what a perpendicular?

514. What do you understand by the *angular measure* of an angle? Do the diameter and radius of a circle always bear the same proportion to the circumference? What proportion does the diameter of a circle bear to its circumference? Formulate this. What Greek letter has been adopted to express the number 3·14159?

515. Explain the properties of a plane triangle and of a spherical triangle. What property is common to all triangles? What is understood by the *sine?* What branch of mathematics teaches us the properties of triangles?

516. What is understood by *trigonometrical ratios?* Give them as stated in the book.

517. What is *spherical* astronomy?

518. What is a *graduated arc?* To what extent is this graduation carried? What do you understand by the circles being correctly centred? What is meant by an instrument being correctly *collimated?*

519. What is a *micrometer,* or a micrometer eye-piece? How is the angular value of each revolution determined? What is a *position circle?* Describe its use.

520. For what do astronomers use the sextant? What else must the astronomer know besides the simple angular distance of one celestial body from another?

521. When we wish to determine positions on the visible portion of the sky, what instrument is used? What must we necessarily know before we can ascertain by calculation the right ascension and declination of the body whose altitude and azimuth in the sphere of observation we had instrumentally determined?

522. Describe an altazimuth, and illustrate its use.

523. How ought one to proceed in making an observation with the altazimuth?

LESSON XLII.—*The Transit Circle and its adjustment—Principles of its use—Method of taking Transits — The Chronograph — The Equatorial.*

524. When wishing to determine directly the position of a celestial body on the celestial sphere itself, what instrument do you use? Describe this transit circle and its use. Describe the transit circle in use at Greenwich Observatory.

525. When will the northern celestial pole lie in England? Does the pole-star mark exactly the position of the pole? In determining the north polar distance of a celestial body, what has to be done?

526. Seeing that the pole-star does not exactly mark the position of the pole, what method have astronomers adopted? What four points does this method give us from which, with our transit circle, we can measure angular distances?

527. What other co-ordinate is required to fix the position of a heavenly body?

528. Why does a sidereal clock at any place denote the right ascension of the celestial meridian visible in the transit circle at that moment? What more is necessary to determine the right ascension and declination of a celestial body? What is it that most assists us in making these observations?

529. Is this method good for mapping the whole heavens? To whom do we owe the best catalogue of the positions of the heavenly bodies? How many stars has he determined the positions of? Who besides have published catalogues?

530. Do all these observations require much delicacy?

531. Show this by reference to the system adopted at Greenwich.

532. What are the methods of observing the time of transit over a wire? Describe the former method.

533. Describe the galvanic method.

534. What other name is this method known by? What are the advantages of the method?

535. Where must a star be, before its position can be determined by the transit circle? What advantage in this respect does the equatorial possess over the transit circle? What is the method adopted? Show in what way the right ascension is determined.

LESSON XLIII.—*Corrections applied to observed places—Instrumental and Clock errors—Corrections for Refraction and Aberration—Corrections for Parallax—Corrections for Luni-solar Precession — Change of Equatorial into Ecliptic Co-ordinates.*

536. The astronomer having thus obtained the observed or apparent place of a body, what has he to do in order to verify its true place? Do certain properties of light render further corrections necessary? What is the effect of refraction? What is the difference between its action at the zenith and near the horizon?

537. Give some idea of the correction for refraction from the table in the book.

538. Are any further corrections necessary? What necessitates such further correction?

539. What does aberration result from? Is the star's aberration place, then, coincident with its real place? Explain and illustrate this. What quantity is termed the *constant of aberration?* What does this express? Give the proportion which determines it. Show, by Fig. 55, the mode by which the correction for aberration is applied.

540. Give another name for the Earth's motion in its orbit. What is the direction of this motion as compared with the Sun's position in the ecliptic at the time? Where, consequently, must the aberration of the star lie?

541. What is the reason that observations of celestial bodies near the Earth, such as the Moon and some of the planets, when made at different places on the Earth's surface, and corrected as already pointed out, do not give the same result?

542. How then are such discrepancies got rid of? What name have astronomers given this? What is *parallax?* What is the *horizontal* parallax? When the body is in the zenith of an observer, what is its parallax?

543. How is the value of the correction for parallax found?

544. Formulate this further.

545. What are the two fundamental planes by means of either of which we have thus seen the positions of bodies are determined on the celestial sphere? What is the intersection occupied by the Sun at the vernal equinox called? How then is the declination reckoned? The celestial latitude? Right ascension, and celestial longitude?

546. Is the plane of the Earth's yearly motion in the direction of the inclination of the Earth's axis always the same? What does this change render necessary?

547. What is now known about the changes in position of the Earth's pole?

548. What follows from this change of the Earth's axis? What is this called? What results from this? Where was the Sun at the vernal equinox 2000 years ago? In what constellation is he now?

549. Is the plane of the ecliptic also subject to variation? What is this variation called?

550. Of these changes, which is the most important? What does it cause? To what is the difference between the sidereal and tropical year attributed?

551. What is the cause of these changes? What is the effect? Will, consequently, the observed position of a heavenly body to-day be the same it occupied last year, or will occupy next year? What do astronomers do in this case?

552. How do astronomers determine the coordinates, celestial latitude and longitude?

553. What is the first thing to be done? What is the *obliquity of the ecliptic?* How is the obliquity of the ecliptic determined?

554. Describe how, when ω is known, RA. and Decl. are transformed into lat. and long.

LESSON XLIV.—*Summary of the methods by which true positions of the Heavenly Bodies are obtained—The use that is made of these positions—Determination of Time: of Latitude: of Longitude.*

555. Summarize what has hitherto been said in this chapter.

556. What have astronomers been enabled to do by means of such observations?

557. What have astronomers been further enabled to do? What do the positions of the stars, planets, of the Sun from day to day, and of the Moon from hour to hour, enable us to determine?

558. What instrument is employed when time only is required? Describe a *transit* instrument. What time does it give us?

559. Describe how, in a fixed observatory with the proper instruments, you are able to determine latitude.

560. Express all this more briefly.

561. Describe how explorers, or those on shipboard, determine latitude.

562. What is longitude?

563. What is the most convenient way of determining longitude in a fixed observatory?

564. What does the problem consist of at sea, and what are the methods adopted to solve it?

565. Describe the second method.

566. What is the third method?

CHAPTER VIII.

DETERMINATION OF THE REAL DISTANCES AND DIMENSIONS OF THE HEAVENLY BODIES.

LESSON XLV.—*Measurement of a Base-line—Ordnance Survey—Determination of the Length of a Degree—Figure and Size of the Earth—Measurement of the Moon's distance.*

567. UPON what are all measurements based? Describe the method of determining the Moon's or a planet's parallax.

568. Is it possible to determine the Sun's parallax? Why so?

569. What difference is there between a surveyor's finding the distance of a tower and an astronomer's determining the distance of a star?

570. How has the size of the Earth been ascertained? Describe the process.

571. What part does the theodolite play in such measurements?

572. When all the triangulations were complete, how was their accuracy proved? How has the map of the United Kingdom been constructed?

573. How do we connect the map of England with the size of the Earth?

574. If we could walk in a straight line from the equator to the pole, what would our relation be to

the stars when we began and ended the journey? And if this distance could be measured, what portion of the Earth's circumference would it truly represent?

575. As this is impossible, what method has been adopted by astronomers to measure the Earth? Describe it.

576. Is the length of a degree the same in all latitudes? Give a few of the known variations. What follows from these measurements?

577. What do the varying lengths of a degree enable us to determine? State the diameter of the Earth, equatorial and polar. What else have the various triangulations of the Earth taught us?

578. Does this knowledge of the exact dimensions of the Earth enable us to determine the distance between any two places the positions of which on the Earth's surface are accurately known?

579. Show how we are in this way able to measure the distance of the Moon.

580. Illustrate this further by a reference to the diagram.

581. By this same method, what has the mean equatorial horizontal parallax of the Moon been proved to be?

LESSON XLVI.—*Determination of the distances of Venus and Mars: of the Sun—Transit of Venus—The Transit of* 1882.

582. Under what circumstances can we apply this method to the determining the distances of Venus and of Mars?

583. Is there any other method of determining

his distance when Mars is in opposition? Refer to the diagram, and describe it.

584. Why cannot the Sun's distance be measured in this way?

585. What is the method, then, we adopt? and who first pointed it out?

586. Why is Venus the best planet to attack by the base-line method? What is a *transit of Venus?* Are such transits frequent? When was the last? and when will be the next? What purpose does the Sun serve during a transit of Venus?

587. Refer to the diagram, and show how we accomplish the measurement of the Sun's distance. Is it important that we know the amount of separation of the chords?

588. What are the relative distances of Venus from the Earth and the Sun? What relations do the absolute distances bear to the two chords? Illustrate this.

589. How would simultaneous photographs of the Sun from the two stations affect the question?

590. As such observations are out of the question, how does the astronomer gain his object? What is it in this observation which determines the amount of separation?

591. How and why do we make the difference between the observed lines of transit as great as possible? Take the transit of 1882, and, referring to the diagram, illustrate this further.

592. At what part of the Earth would the duration of the transit be shortest? At what spot on the Earth's surface would the duration of the transit be longest? Why do we choose a spot for observation where the ingress will be accelerated, and another where the egress will be retarded?

LESSON XLVII. — *Comparison of the old and new Values of the Sun's distance—Distance of the Stars—Determination of real Sizes.*

593. What is the Sun's distance, as obtained from the observations of the last transit? What the value of the distance determined by other means? Can you give the various values of the parallax as stated by astronomers? Give a familiar illustration of the difference between the old and new values.

594. Enumerate the steps which have thus led up to our obtaining the distance of the Sun. What fresh base of operations does this knowledge of the Sun's distance give us? What is the length of this base-line? As seen from the fixed stars, what would be the appearance of this line? With an ordinary instrument, what distance would a parallax of 1″ represent? If the star's parallax is less than a second, what distance must the star be off?

595. In most cases, however, does the true zenith-distance of a star vary? Why not? Who attacked successfully the problem in another manner? Describe his method, and refer to some of the results.

596. Under what conditions, then, is the size of a body determined? What is distance? Throw this into an equation.

597. Illustrate this by determining the real diameter of the Moon.

598. Knowing the real and also the apparent angular diameter, how can we determine the distance?

CHAPTER IX.

UNIVERSAL GRAVITATION.

LESSON XLVIII.—*Rest and Motion—Parallelogram of Forces—Law of Falling Bodies—Curvilinear Motion—Newton's Discovery—Fall of the Moon to the Earth—Kepler's Laws.*

599. WHAT stops bodies set in motion?

600. What do you understand by a *resultant?*

601. Illustrate this compound motion by reference to the diagram.

602. From what do we get our idea of weight? Show how the atmosphere appears to affect the gravity of things? Demonstrate that it is not so. How is gravity, or attraction, measured?

603. At what rate do bodies fall? Give the equation.

604. Illustrate what you understand by *curvilinear motion.*

605. Who first propounded the law of gravitation? What was the method of his observation?

606. Formulate this law. How is the intensity of a force measured?

607. Illustrate this. What did Galileo teach the old schoolmen in this respect?

608. From our definition of gravity, and from the well-known law that every action has a reaction,

what would one be justified in predicating of the Earth where the weight is dropped? Does it do so?

609. Were the Earth twice as large, what would be the rate of velocity produced in a second of time? And what the rate were it only half as large?

610. What would consequently be the state of attraction at the surface of the Moon and at that of the Sun? We have seen that a falling body at the end of one second has a velocity of $32\frac{1}{6}$ feet per second. Has it actually fallen that distance during the second? What, then, will be its mean velocity during the first second? Supposing this body were at the distance of the Moon, or sixty times as far off, at what rate would it fall?

611. Illustrate this by reference to Fig. 66.

612. Show in what respect, and why, the Moon's curved path represents that of our cannon-ball. Show what relation a body falling at the Moon's distance bears to one falling on the Earth's surface.

613. What is the deflection, then, produced in the Moon's orbit from the tangent to its path in one second? What calculation was it which revealed to Newton the law of gravitation?

614. Do you remember Kepler's three great laws?

615. What is the *radius-vector* of a planet? Do you remember why it was that planets moved faster as they approached the Sun? What does Law II. tell us?

616. Refer to Fig. 67, and illustrate by it Kepler's second law.

617. What does the third law teach us? Show the distance of Jupiter from the Sun by a simple proportion.

618. Prove by the table the truth of Kepler's third law.

LESSON XLIX.—*Kepler's Second Law proved—Centrifugal tendency—Centripetal Force—Kepler's Third Law proved—The Conic Sections—Movement in an Ellipse.*

619. Why was not Kepler able to see the hidden meaning of his own laws? For whom was this glory reserved?

620. Was Newton able to show that Kepler's laws established the truth of gravitation? Prove Kepler's second law by reference to Fig. 68.

621. Give a familiar illustration of the tendency of bodies to keep in the direction of their original motion.

622. Show, by aid of equations, what you understand by *centrifugal tendency*, and by *centripetal force.*

623. Show in what way this formula can be applied to the planets.

624. What must the orbit of a smaller body round a larger one necessarily be? What determines the precise form? Did Newton show that attraction is proportional to the product of the masses of the bodies? Give an example. Were the attraction of the central body to cease, what would result? And what, were the centrifugal tendency to cease?

625. How is it that equal areas are swept over in equal times?

626. Show, by reference to Fig. 71, how the varying velocities of a body revolving in an orbit are caused and controlled.

LESSON L.—*Attracting and Attracted Bodies considered separately—Centre of Gravity—Determination of the Weight of the Earth: of the Sun: of the Satellites.*

627. What is universally true regarding every particle of matter?

628. Is the attraction of one body on another at the same distance perfectly independent of the mass of the attracted body? Give an illustration.

629, 630. Give a second law on this subject, and a third.

631. What do you understand by the *centre of gravity?* Show the operation of this by reference to the Sun and Earth.

632. What must necessarily be known before we can determine the mass of the Sun and the masses of those planets which have satellites? Show the process by which we attain a knowledge of the masses of the Sun and of the planets.

633. Does attraction possess any other besides that of controlling force? Give examples.

634. Explain what you mean by *specific gravity.*

635. Give the various methods which have been used to determine the density of the Earth.

636. Who adopted the first method? What was Cavendish's mode of procedure?

637. State the results at which he arrived. What, then, in round numbers, is the weight or

mass of the Earth? How do astronomers express this?

638. Explain the process by which we arrive at the mass of the Sun. What is the weight?

639. How is this method applied to the satellites?

640. Show how we may determine the Sun's mass from equation. Can we determine the mass of planets in a similar way?

641. How do you determine the gravity on the surface of the Sun or of a planet compared to that on our Earth?

LESSON LI.—*General effect of Attraction—Precession of the Equinoxes: how caused—Nutation—Motions of the Earth's Axis—The Tides—Semi-diurnal, Spring, and Neap Tides—Cause of the Tides—Their probable effect on the Earth's Rotation.*

642. What, then, have the laws of Kepler and of Newton shown?

643. Explain what you understand by the terms *perturbations, inequalities, and secular inequalities.*

644. Do these perturbations and their results form difficult subjects in the domain of astronomy?

645. Illustrate familiarly the Sun's attraction on the equatorial protuberance of the Earth.

646. What complicates the Sun's attraction on the equatorial protuberance?

647. What would result were the Earth at rest? What prevents this? What result has this attrac-

tion of the Sun on the protuberance? What is the compound result of the Earth's rotation and the Sun's attraction?

648. Explain how we get the term *precession.*

649. What else plays an important part in averaging the precessional motion of the entire planet during the year?

650. What part does the Moon play in precession? What is her precessional action compared with that of the Sun?

651. What is the change in the position of the equator, which follows from the rolling motion, necessarily connected with?

652, 653. Illustrate this by a reference to Fig. 76.

654. To what is *nutation* due?

655. Explain what you understand by the term by a reference to Fig. 77.

656. In what position will the precessional effect be small, and when will it be the greatest possible?

657. What movement is there besides the circular movement of the axis? What would nutation produce were the pole at rest? But as the two motions are compounded, what is the result? Explain this by reference to Fig. 78.

658. In what lesson has the effect of these motions of the Earth's axis on the apparent position of the heavenly bodies been demonstrated?

659. At what intervals do the waters of the ocean rise and fall?

660. When have we *spring tides,* and wherein do they differ from ordinary tides? When have we *neap tides,* and what is their characteristic? To what are these phenomena owing?

661. Represent by equation the Earth's action on a particle of water at its surface, and the action of the Sun on that same particle. In like manner show how the differential attraction of the Moon is much greater than in the case of the Sun.

662. State generally, then, the cause of the semi-diurnal tides, and of the semi-monthly variation.

663. Explain how we come to have two daily tides on the surface of the Earth.

664. Does high water depend solely upon the direct attraction of our satellite? What do you understand by the *tangential component of the attraction?* In what direction does it act to the Earth's gravity? In what direction does the immediate attraction of the Moon act? Which of the two is the greater force?

665. Does the difference of latitude between the two bodies influence tides as well as the Sun and Moon in longitude? When will the spring tide be highest?

666. What complicates the phenomena of the tides? What do you understand by the term, *establishment of the port?*

667. What is the velocity of the tidal undulation in the open ocean? To what extent is this speed retarded in shallow waters? What is the average height of the tide round the islands in the Atlantic and Pacific oceans? What at the head of the Bay of Fundy? In what direction does the tidal wave appear to move? To what suggestion has this apparent backward movement given rise? If the sidereal day be assumed to be invariable, is it possible to represent the Moon's true place at intervals of 2000 years

apart by the theory of gravitation? On this assumption, by what amount of time would the Moon, looked upon as a timepiece, be too fast? To what fact may this be due? If the sidereal day is shortening in consequence of the tidal action, at what has the rate been calculated?

THE END.

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